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DESCRIPTION

ZOOM LENS AND IMAGING APPARATUS

Technical Field

The present invention relates to a zoom lens that is compact, that has a high variable rate, and that is well suited for adaptation in photography optical systems of digital input and output apparatuses, such as digital still cameras and digital video cameras. The invention further relates to an image apparatus using the zoom lens.

Background Art

In recent years, imaging apparatuses, such as digital still cameras, using the solid state image devices have been widely spread. With widespread use of such digital still cameras, correspondingly higher image quality is demanded. In particular, photography lenses, especially, zoom lenses having high imaging performance corresponding to solid state image devices having a large number of pixels are sought for the use with a digital still camera having a large number of pixels. Further, compactness is strongly demanded, and compact and high performance zoom lenses are sought. Further, technological development advances to enhance compactness in the optical axis direction in the manner that a prism is inserted between lenses and the optical system is bent (refer to Japanese Unexamined Patent Application Publications Nos. 8-248318

and No. 2003-43354, for example).

However, in the optical system disclosed in Japanese Unexamined Patent Application Publication No. 8-248318, compactness is achieved in the manner that a prism is used in one group of a zoom type arrangement of positive-negative-positive-positive groups to thereby bend the optical axis. However, since lenses are arranged closer to the object side than to a reflection member, sufficient compactness cannot be achieved.

In the optical system disclosed in Japanese Unexamined Patent Application Publication No. 2003-43354, a prism having a negative refraction power is disposed on the most object side, whereby compactness of a bent portion is achieved. However, since the configuration is of a minus lead type, a diaphragm mechanism is large and the diaphragm mechanism moves along the optical axis during zooming, so that sufficient compactness for those including a lens barrel is not sufficiently achieved.

Disclosure of Invention

The present invention is made to solve problems such as described above. More specifically, the present invention provides a zoom lens including a plurality of lens groups and performing zooming by changing an inter-group distance, in which, of the plurality of lens groups, a lens group on a most object side has a positive refractive power and is fixed, a reflection member for

bending an optical axis is provided in that lens group, and the reflection member is formed of a prism having a negative refractive power. Further, an imaging apparatus using the zoom lens is provided.

In addition, the present invention provides a zoom lens including a plurality of lens groups and performing zooming by changing an inter-group distance, the zoom lens being characterized in that a reflective member for bending an optical axis is disposed in a lens group on a most object side of the plurality of lens groups, the reflection member is formed of a prism having a negative refractive power, and an aperture position is fixed during zooming. Further, an imaging apparatus using the zoom lens is provided.

According to the present invention, by bending the optical system, compactness in the optical axis direction can be achieved, and a zoom lens excellent in optical characteristics can be configured.

Consequently, the present invention enables improving the imaging performance and achieving compactness of zoom lenses for use with, for example, video cameras and digital still cameras.

Brief Description of the Drawings

FIG. 1 is a lens configuration diagram of a zoom lens according to a first embodiment in a short focal distance position.

FIG. 2 is a lens configuration diagram of a zoom lens according to a second embodiment in a short focal distance position.

FIG. 3 is a lens configuration diagram of a zoom lens according to a third embodiment in a short focal distance position.

FIG. 4 shows various aberration diagrams of the zoom lens according to the first embodiment in the short focal distance position.

FIG. 5 shows various aberration diagrams of the zoom lens according to the first embodiment in an intermediate focal distance position.

FIG. 6 shows various aberration diagrams of the zoom lens according to the first embodiment in a long focal distance position.

FIG. 7 shows various aberration diagrams of the zoom lens according to the second embodiment in the short focal distance position.

FIG. 8 shows various aberration diagrams of the zoom lens according to the second embodiment in an intermediate focal distance position.

FIG. 9 shows various aberration diagrams of the zoom lens according to the second embodiment in a long focal distance position.

FIG. 10 shows various aberration diagrams of the zoom lens according to the third embodiment in the short focal distance position.

FIG. 11 shows various aberration diagrams of the zoom lens according to the third embodiment in an intermediate focal distance position.

FIG. 12 shows various aberration diagrams of the zoom lens according to the third embodiment in a long focal distance position.

Best Mode for Carrying Out the Invention

An embodiment and examples of the present invention will be described herebelow. An embodiment is characterized in that in a zoom lens, a reflection member for bending an optical axis is included in one fixed lens group having a positive refractive power, and the reflection member is formed of a prism having a negative refractive power

More specifically, a zoom lens according to the present embodiment includes a plurality of lens groups and performs zooming by changing an inter-group distance, in which, of the plurality of lens groups, a lens group on a most object side has a positive refractive power and is fixed, a reflection member for bending an optical axis is provided in the lens group, and the reflection member is formed of a prism having a negative refractive power. In this case, the reflection member may be disposed on the most object side.

In addition, a zoom lens according to the present embodiment includes a plurality of lens groups and

performing zooming by changing an inter-group distance, in which a reflective member for bending an optical axis is disposed in a lens group on a most object side of the plurality of lens groups, the reflection member is formed of a prism having a negative refractive power, and an intermediate aperture position is fixed during zooming. In this case, the reflection member may be disposed on the most object side.

Preferably, in the zoom lens according to the present embodiment, an aperture is fixed during zooming.

In addition, preferably, in the zoom lens according to the present embodiment, the reflective member is formed of a prism satisfying Conditional Expression (1):

$1.7 < Npd$ (Conditional Expression (1))

where,

Npd = refraction index of the prism forming the reflective member.

Conditional expression (1) defines the refraction index of the reflection member. In the case that the refraction index of the prism is lower than or equal to a lower limit of Conditional Expression (1), increasing the refraction index of the prism causes the curvature of an incident surface to be excessively increased, thereby making it difficult, for example, to correct distortion and image plane and to achieve the compactness.

In addition, the prism preferably satisfies Conditional Expression (2):

$1.8 < Npd$ (Conditional Expression (2))

where,

Npd = refraction index of the prism forming the reflective member

Preferably, the prism having the negative refractive power is formed by molding. However, the prism may be formed by cementing a lens with a prism. Further, distortion may be corrected using a process of electric signals.

Embodiments

Embodiments of the present invention will be described hereinbelow. FIG. 1 is a configuration diagram of a zoom lens according to a first embodiment. Arrows in the drawing indicate movement paths of respective lens groups from a wide-angle end position to a telescopic end position. The zoom lens according to the first embodiment is configured, in order from an object side, a positive first lens group GR1, a negative second lens group GR2, a positive third lens group GR3, a positive fourth lens group GR4, and a negative fifth lens group GR5. The first lens group GR1 includes a prism G1, which has a negative refractive power for 90° bending the optical axis, and a positive lens G2 having two aspheric surfaces.

The second lens group GR2 includes a negative lens G3 and a cemented lens of a negative lens G4 and a positive lens G5. The third lens group GR3 includes a positive lens G6 having two aspheric surfaces.

The fourth lens group GR4 is formed of a cemented lens of a positive lens G7, which has an aspheric surface on the object side, and a negative lens G8. The fifth lens group GR5 includes a cemented lens of a negative lens G9 and a positive lens G10, and a positive lens G11 having an aspheric surface on the object side.

FIG. 2 shows a configuration diagram of a zoom lens according to a second embodiment. Arrows in the drawing indicate movement paths of respective lens groups from a wide-angle end position to a telescopic end position. The zoom lens according to the second embodiment includes, in order from an object side, a positive first lens group GR1, a negative second lens group GR2, a positive third lens group GR3 having an aspheric surface on the object side, a positive fourth lens group GR4, and a negative fifth lens group GR5. The first lens group GR1 includes a cemented lens of a prism G1, which has an aspheric surface on the object side, and a rectangular prism P for 90° bending the optical axis, and a positive lens G2 having two aspheric surfaces.

The second lens group GR2 includes a negative lens G3 and a cemented lens of a negative lens G4 and a positive lens G5. The third lens group GR3 is formed of a positive lens G6 having two aspheric surfaces.

The fourth lens group GR4 includes a cemented lens of a positive lens G7, which has an aspheric surface on the object side, and a negative lens G8. The fifth lens group

GR5 includes a cemented lens of a negative lens G9 and a positive lens G10, and a positive lens G11 having an aspheric surface on the object side.

FIG. 3 shows a configuration diagram of a zoom lens according to a third embodiment. Arrows in the drawing indicate movement paths of respective lens groups from a wide-angle end position to a telescopic end position. The zoom lens according to the third embodiment includes, in order from an object side, a positive first lens group GR1, a negative second lens group GR2, a positive third lens group GR3, a positive fourth lens group GR4, and a negative fifth lens group GR5. The first lens group GR1 is configured of a prism G1, which has an aspheric surface on the object side, and a rectangular prism P for 90° bending the optical axis, and a positive lens G2 having two aspheric surfaces.

The second lens group GR2 includes a negative lens G3 and a cemented lens of a negative lens G4 and a positive lens G5. The third lens group GR3 is formed of a positive lens G6 having two aspheric surfaces.

The fourth lens group GR4 is formed of a cemented lens of a positive lens G7, which has an aspheric surface on the object side, and a negative lens G8. The fifth lens group GR5 is configured of a cemented lens of a negative lens G9 and a positive lens G10, and a positive lens G11 having an aspheric surface on the object side.

Tables 1 to 3 below show data of the zoom lenses

according to the first to embodiments.

TABLE 1

FNo. = 3.60 ～ 3.88 ～ 4.44
f = 6.91 ～ 11.62 ～ 19.55
ω = 29.97 ～ 17.80 ～ 10.67

Surface No.	R		d	nd	νd
1:	-12.158	(ASP)	4.210	1.84666	23.785
2:	INFINITY	(Reflective surface)	4.210	1.84666	23.785
3:	28.998	(ASP)	0.500		
4:	8.370	(ASP)	2.467	1.80611	40.734
5:	-23.519	(ASP)	0.500 ～ 3.588 ～ 5.813		
6:	-513.611		0.500	1.83500	42.984
7:	7.082		0.906		
8:	-12.247		0.450	1.80420	46.503
9:	6.447		1.150	1.92286	20.884
10:	30.533		5.813 ～ 2.725 ～ 0.500		
11:	9.684	(ASP)	1.576	1.69350	53.201
12:	-41.858	(ASP)	1.000		
13:	Aperture		6.610 ～ 4.389 ～ 2.045		
14:	13.103	(ASP)	2.267	1.69350	53.201
15:	-5.264		0.550	1.80518	25.456
16:	-14.202		2.703 ～ 4.924 ～ 7.267		
17:	-85.495		0.500	1.83400	37.345
18:	4.379		2.300	1.49700	81.608
19:	25.455		2.500		
20:	12.953	(ASP)	1.487	1.84666	23.785
21:	77.234		2.368		
22:	INFINITY		1.700	1.51680	64.198
23:	INFINITY		1.120		
24:	INFINITY		0.500	1.51680	64.198
25:	INFINITY				

Surface No.	ε	A^4	A^6	A^8	A^{10}
1	1	0.695009E-03	-0.769817E-05	0.175714E-07	0.119437E-08
3	1	-0.705248E-03	0.143439E-03	-0.907799E-05	0.242336E-06
4	1	-0.184995E-02	0.143335E-03	-0.958467E-05	0.204369E-06
5	1	-0.657112E-03	0.302629E-04	-0.303252E-05	0.612240E-07
11	1	0.267075E-03	-0.387128E-04	0.854256E-05	-0.314089E-06
12	1	0.582935E-03	-0.354368E-04	0.876895E-05	-0.315734E-06
14	1	-0.120598E-03	0.291949E-05	-0.171268E-06	0.112251E-07
20	1	-0.250658E-04	0.122110E-05	0.565389E-06	-0.225582E-07

TABLE 2

FNo. = 3.60 ~ 3.86 ~ 4.36
f = 6.90 ~ 11.62 ~ 19.55
ω = 29.98 ~ 17.81 ~ 10.66

Surface No.	R	d	nd	νd
1:	-12.0223 (ASP)	0.600	1.84666	23.785
2:	INFINITY	4.350	1.84666	23.785
3:	INFINITY (Reflective surface)	4.350	1.84666	23.785
4:	INFINITY	0.400		
5:	8.583 (ASP)	2.346	1.77377	47.200
6:	-71.247 (ASP)	0.518 ~ 3.615 ~ 5.899		
7:	36.344	0.500	1.83500	42.984
8:	6.109	1.041		
9:	-11.555	0.450	1.80420	46.503
10:	5.921	1.150	1.92286	20.884
11:	27.935	5.881 ~ 2.784 ~ 0.500		
12:	9.555 (ASP)	1.554	1.69350	53.201
13:	-42.514 (ASP)	1.000		
14:	Aperture	6.200 ~ 4.152 ~ 2.032		
15:	11.826 (ASP)	2.267	1.69350	53.201
16:	-5.549	0.550	1.84666	23.785
17:	-14.233	2.508 ~ 4.556 ~ 6.676		
18:	-39.634	0.500	1.80610	33.269
19:	4.149	2.400	1.49700	81.608
20:	13.820	2.600		
21:	13.333 (ASP)	1.752	1.84666	23.785
22:	-43.749	2.400		
23:	INFINITY	1.700	1.51680	64.198
24:	INFINITY	1.120		
25:	INFINITY	0.500	1.51680	64.198
26:	INFINITY			

Surface No.	ε	A^4	A^6	A^8	A^{10}
1	1	0.593353E-03	-0.816542E-05	0.111330E-06	-0.675203E-09
5	1	-0.493322E-03	-0.687128E-05	0.916164E-07	-0.278994E-07
6	1	-0.641626E-04	-0.386299E-05	-0.643382E-06	-0.259664E-09
12	1	0.430269E-04	-0.354837E-04	0.341845E-05	-0.786579E-07
13	1	0.322425E-03	-0.318420E-04	0.319048E-05	-0.762601E-07
15	1	-0.159259E-03	0.863017E-05	-0.901992E-06	0.329121E-07
21	1	-0.380161E-04	0.184757E-05	0.406406E-06	-0.131998E-07

TABLE 3

FNo. = 3.60 ~ 3.83 ~ 4.35
f = 6.91 ~ 11.62 ~ 19.61
ω = 33.05 ~ 18.36 ~ 10.65

Surface No.	R	d	nd	νd
1:	-20.146	0.500	1.84666	23.785
2:	INFINITY	4.480	1.92286	20.884
3:	INFINITY (Reflective surface)	4.480	1.92286	20.884
4:	INFINITY	0.400		
5:	15.683 (ASP)	2.267	1.77377	47.200
6:	-19.392 (ASP)	0.500 ~ 3.492 ~ 5.624		
7:	35.414	0.500	1.88300	40.805
8:	5.866	1.088		
9:	-8.543	0.450	1.80420	46.503
10:	5.999	1.150	1.92286	20.884
11:	47.158	5.624 ~ 2.632 ~ 0.500		
12:	10.970 (ASP)	1.667	1.58913	61.251
13:	-13.076 (ASP)	1.000		
14:	Aperture	6.609 ~ 4.354 ~ 2.032		
15:	10.229 (ASP)	2.762	1.58913	61.251
16:	-5.504	0.550	1.92286	20.884
17:	-9.874	1.737 ~ 3.993 ~ 6.314		
18:	-75.817	0.500	1.83400	37.345
19:	4.959	2.440	1.49700	81.608
20:	8.130	2.900		
21:	14.663 (ASP)	1.905	1.84666	23.785
22:	-22.823	2.300		
23:	INFINITY	1.700	1.51680	64.198
24:	INFINITY	1.120		
25:	INFINITY	0.500	1.51680	64.198
26:	INFINITY			

Surface No.	ε	A^4	A^6	A^8	A^{10}
5	1	-0.105956E-03	-0.586460E-06	-0.706848E-08	-0.806784E-08
6	1	0.267324E-04	0.922398E-06	-0.181160E-06	-0.288624E-08
12	1	-0.859121E-04	-0.141438E-04	0.504154E-06	0.203452E-07
13	1	0.234640E-03	0.174123E-04	-0.470843E-05	0.312608E-06
15	1	-0.157450E-03	0.314827E-04	-0.519568E-05	0.312610E-06
21	1	0.333160E-04	-0.144255E-04	0.107968E-05	-0.251109E-07

In each of the tables, "FNo." indicates the F number; "f" indicates the focal distance; "ω" indicates the half angle of viewing; "R" indicates the radius of curvature,

"d" indicates the inter-lens surface distance; "nd" indicates the refraction index with respect to the d line; and "vd" indicates the Abbe number. In addition, each respective surface shown with "(ASP)" is an aspheric surface, and the aspheric surface profile is represented by equation 1 below.

(Equation 1)

$$x = \frac{y^2 \cdot c^2}{1+\sqrt{1-\varepsilon \cdot y^2 \cdot c^2}} + \sum A^i \cdot Y^i$$

where,

x = distance in the optical axis direction from the lens surface apex

y = height in the direction perpendicular to the optical axis

c = paraxial curvature at the lens apex

ε = conic constant

A^i = ith aspheric surface coefficient

Table 4 below shows respective numeric values for satisfying conditions of Conditional Expression (1) for the zoom lenses shown and described in conjunction with the first to third embodiments.

TABLE 4

Coditional expression	First embodiment	Second embodiment	Third embodiment
(1) Npd	1.847	1.847	1.923

FIGS. 4 to 12, respectively, shows various aberration diagrams of the zoom lens according to the first embodiment in short small focal distance end positions. FIG. 4 shows various aberration diagrams according to the first embodiment in a short focal distance end position; FIG. 5 shows various aberration diagrams according to the first embodiment in an intermediate focal distance end position; and FIG. 6 shows various aberration diagrams according to the first embodiment in a long focal distance end position. FIG. 7 shows various aberration diagrams according to the second embodiment in a short focal distance end position; FIG. 8 shows various aberration diagrams according to the second embodiment in an intermediate focal distance end position; and FIG. 9 shows various aberration diagrams according to the second embodiment in a long focal distance end position. FIG. 10 shows various aberration diagrams according to the third embodiment in a short focal distance end position; FIG. 11 shows various aberration diagrams according to the third embodiment in an intermediate focal distance end position; and FIG. 12 shows various aberration diagrams according to the third embodiment in a long focal distance end position.

In the respective diagram, for the spherical aberration, the vertical axis represents the ratio to an open F-number, the horizontal axis represents the defocus, a solid line is the d line, a broken line is the c line, and a single-dotted chain line is the g line. For the

astigmatism, the vertical axis represents the image height, the horizontal axis represents the focus, the solid line represents a sagittal image plane, and the broken line represents a meridional image plane. For the distortion aberration, the vertical axis represents the image height, and the horizontal axis represents the distortion (%).

In the respective one of the zoom lens according to the first to third embodiments, as apparent from Table 4, Conditional Expression (1) is satisfied. In addition, as apparent from the respective aberration diagram, the respective aberrations are corrected with good balancing in the wide-angle end position, intermediate focal distance position between the wide-angle end position and the telescopic end position, and the telescopic end position.

While the shapes and constructions of the individual portions are described and shown in detail with reference to the embodiment and examples, they are merely practical examples for carrying out the present invention, so that they should not be construed as limiting the technical scope of the invention.

Industrial Applicability

The zoom lens of the present invention is adaptable not only to imaging apparatuses such as digital still cameras and digital video cameras, but also to imaging function portions incorporated in, for example, mobile phones, personal computers, and personal digital assistants

(PDAs).